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B-spline based analysis and control of linear parameter-varying systems

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We present a novel B-spline based solution to analysis and synthesis problems related to multivariate linear parameter-varying (LPV) systems. Specifically, we consider finite-dimensional LPV systems in state-space form

$$\begin{cases} \delta x &= A(\alpha)x + B(\alpha)w, & x(0) = 0, \\ z &= C(\alpha)x + D(\alpha)w, \end{cases} \quad (1)$$

with state $x : \mathbb{T} \rightarrow \mathbb{R}^{n_x}$, input $w : \mathbb{T} \rightarrow \mathbb{R}^{n_w}$, and output $z : \mathbb{T} \rightarrow \mathbb{R}^{n_z}$. δ denotes the derivative (forward shift) operator in continuous (discrete) time. All system matrices are real-valued, bounded, and have a piecewise polynomial dependency on the exogenous parameter $\alpha : \mathbb{T} \rightarrow \mathbb{R}^N$ taking values in a Cartesian product of closed and bounded intervals.

Typically, stability and performance of (1) is guaranteed by solving parameter-dependent (PD) linear matrix inequalities (LMIs). Although these PD LMIs are convex, they are numerically intractable due to the search over infinite dimensional variables and infinitely many parameter values. The latter issue is alleviated by imposing tensor product polynomial spline parameterizations on the optimization variables and replacing the infinite set of constraints by a more restrictive finite set [1].

To limit conservatism of these relaxations, we account for a priori known bounds on the rate of parameter variation. This generally results in a convex polytopic parameter domain, which we transform to a hyperrectangle using a spline mapping. Subsequently, tensor product B-splines are readily exploited to derive relaxations. We demonstrate that the adopted B-spline relaxations provide an elegant and effective solution, featured by numerical efficiency and limited conservatism.

References

- [1] W. Van Loock, E. Lambrechts, G. Hilhorst and G. Pipeleers. Approximate parametric cone programming with applications in control, *European Control Conference*, Aalborg, Denmark, June 2016.

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